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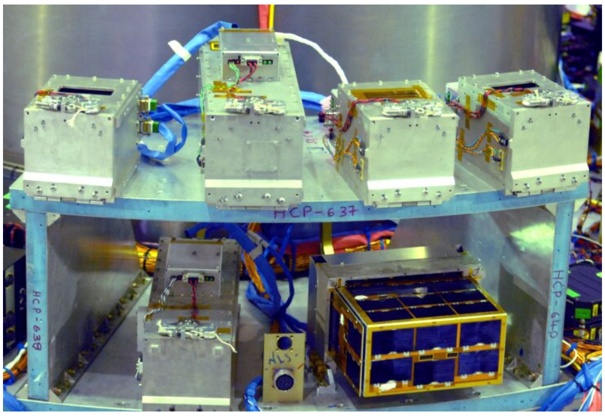


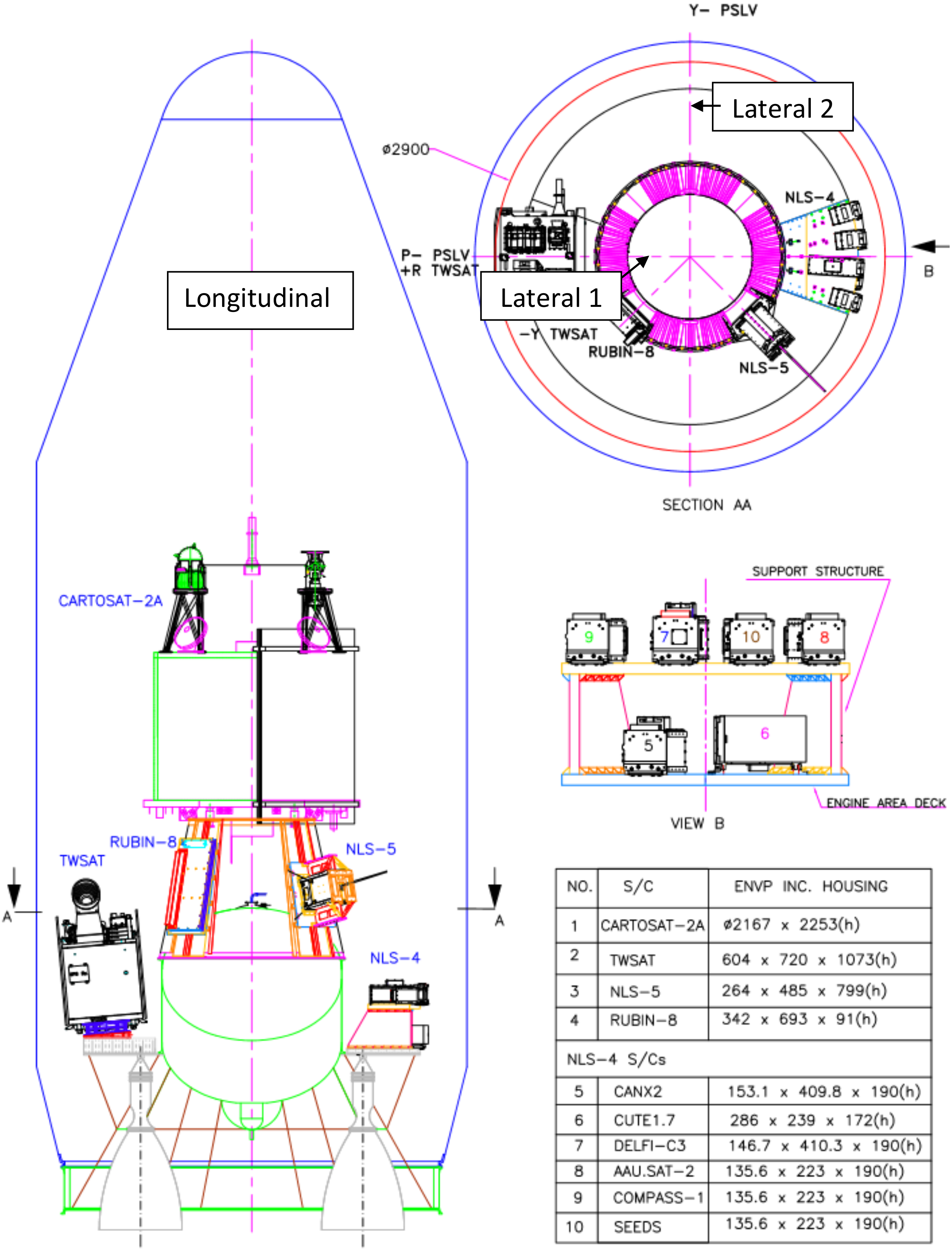
Interface Requirements for launching Auxiliary satellites in PSLV

1 Introduction

PSLV has provision to launch Passenger Payloads of nano and micro satellite class. Satellites weighing 1-3kg are considered as nano-satellites. These satellites are normally mounted on the PSLV-Equipment Bay.

Six such nano-satellites were deployed in PSLV-C9 mission using the customer-supplied separation systems employing a typical mounting configuration as shown in Figure 1.

The Satellites may either use the ISRO developed INLS (ISRO Nano-satellite Launch System) or their own separation system. This document highlights the interface requirements for launch of nano-satellites using INLS or customer supplied separation system in PSLV.



NO.	S/C	ENVP INC. HOUSING
1	CARTOSAT–2A	ø2167 x 2253(h)
2	TWSAT	604 x 720 x 1073(h)
3	NLS–5	264 x 485 x 799(h)
4	RUBIN–8	342 x 693 x 91(h)
NLS–4 S/Cs		
5	CANX2	153.1 x 409.8 x 190(h)
6	CUTE1.7	286 x 239 x 172(h)
7	DELFI–C3	146.7 x 410.3 x 190(h)
8	AAU.SAT–2	135.6 x 223 x 190(h)
9	COMPASS–1	135.6 x 223 x 190(h)
10	SEEDS	135.6 x 223 x 190(h)

Figure 1 Typical mounting configuration of nano-satellites (PSLV-C9)

3 Interfaces requirement for use of Customer-supplied Nano-satellite Separation system

ISRO shall permit use of customer supplied separation system subject to conformance to the requirements mentioned below. A compliance matrix provided at the end of this shall be filled and submitted to PSLV for review and acceptance.

3.1 Design Loads

The separation system shall be designed for the following quasi-static loads

- ±11g Longitudinal (Along vehicle longitudinal direction)
- ±6g Lateral (along vehicle Lateral axes)
- Ultimate Load factor - 1.25
- Design shall consider both longitudinal and lateral loads acting simultaneously.

(Refer Figure 1 for vehicle axis definition)

3.2 Stiffness of separation system

The separation system shall be designed to have stiffness as follows

- >90Hz. Longitudinal (Along vehicle longitudinal axis)
- >45 Hz. Lateral (Along vehicle lateral axes)

3.3 Mechanical Interfaces

The mechanical interface of the separation system with vehicle shall preferably have flanged interface. The system shall be provided with interface for M5 fastener, 4nos/6 Nos for 1kg/3kg class satellites. The location of the interfaces shall be defined by the customer. This needs to be discussed and mutually agreed between the customer and ISRO. The satellite mounting will normally be such that the separation occurs radially, parallel to EB. Refer Figure 2 for definition of dimensional parameters.

3.4 Surface protection

Suitable surface protection treatment shall be ensured for the separation system components. Surface protection treatment of separation system components shall be compatible with space application as the passenger payloads are launched along with main satellites

3.5 Mechanism design

The separation spring shall be designed to impart a relative velocity between 1 & 2 m/s. (Exceptions to be discussed and mutually agreed upon)

For cord based systems, the cord shall be selected as follows

a. Breaking strength of cord shall be at least 5 times of the pre-load in assembly.

b. Proper monitoring the cord pre-load to be devised by the customer.

c. 3 times the actual required length shall be taken from spool, two ends to be used for breaking strength test and the middle piece to be used for flight assembly.

d. The cord selected for flight assembly shall be loaded to 1.25 times of pre-load and kept for one hour before pre-loading for final flight assembly.

e. The relaxation of the cord nominal pre-load in assembled condition to be evaluated for a period of minimum of one month. This relaxation shall not exceed 20% of the pre-load.

f. Life of fully assembled separation system with satellite shall be at least of 1 month. A functional separation test shall be carried out after keeping the system in assembled condition for this duration.

For magnet based systems the magnetic field strength shall not exceed TBD Gauss.

3.6 Electrical Interfaces & circuit design

The following are the criteria to be followed for electrical circuit design of the separation system.

a. The separation system shall be **electrically isolated** from the vehicle.

b. Electrical power to the separation system shall be provided by the separation system itself, with redundancy.

c. PSLV will provide two simultaneous triggering commands of 28V, 500mA (max) for 200ms duration, to initiate the separation system.

d. The triggering commands are to be used for energizing the 'SET' coils of latching relays through the contacts of which the separation system electrical power (batteries) are routed.

e. The electro-mechanical latching relays (MIL-Grade, 15A contact) should be provided in 2S-2P configuration (two relays in series in parallel with another two relays in series). Another 2S-2P configuration is required for routing the redundant battery. (Preferable Part Nos. 4 pole –Type M402J2AH (Leach make) or RBEL 415 143A (Deutch make), 2 pole : M302J2AH/RBEL215147A). The design is to be finalised in consultation with PSLV.

f. Spike suppression diodes (2 Nos. in series) have to be provided across the SET and RESET coils of the relays. The diodes shall be of MIL grade quality [Part No. 1N6642 (MIL-PRF-195-00/578,609) OR 1N5806 (MIL-PRF-195-00/477) or equivalent].

g. The 'RESET Coils' of the relays have to be routed to separate D-type connectors. It has to be ensured that the relays are in RESET condition, after each test. Also before satellite assembly relays have to be in Reset condition.

h. The separation system shall have monitoring devices to give feedback to vehicle telemetry regarding status of separation event. The monitoring device can be either Reed switch or Micro switch. It is required to monitor at least two events namely door opening (if applicable) and completion of stroke. Each type of the monitoring device shall have redundancy.

i. The monitoring contacts (Reed/Micro switch) should be in 'Normally closed' condition at vehicle lift off. These switches should be 'OPEN' at satellite separation. These have to be dry contacts, with both leads routed to the vehicle interface connectors (redundant monitoring through redundant connector).

j. The inadvertent operation of micro-switches shall not activate RF systems immediately. RF systems shall be ON only after a delay as defined in Table 4.

k. Provision for non-intrusive current monitoring of the relay coil current (corresponding to the trigger signal) is desirable. Coil current shall be monitored through Hall effect sensor. If the monitoring is provided, the sensor excitation will be provided from PSLV.

l. The electrical interface between the vehicle and separation system shall use standard MIL grade connector of D-type (9 pin, 15 pin or 25 pin). Redundant connectors are to be used for redundant commands and monitoring. The connectors on the separation system shall be of pin type. Identical pin allocation shall be followed for the redundant connectors.

3.7 Environmental Testing

3.7.1 Vibration and shock tests

3.7.1.1 For newly developed system

A separation system that is being developed newly and planned to be flown for the first time shall comply to the following:

- An exclusive system to be realised that shall undergo all mandatory qualification tests as detailed in this section.
- The flight unit shall undergo acceptance testing respectively as detailed in this section.

- The qualification unit shall be subjected to qualification vibration in Sine, Random and Shock in all three axes to levels as in Table 1, Table 2 & Table 3. During qualification test the cord pre-load of the separation system shall be less than nominal flight pre-load by 10%. The health of all the relays in the circuit and the devices for providing feedback to vehicle shall be monitored and recorded. After the completion of the vibration tests (sine & random) a functional separation test shall be conducted. Similarly functional separation test shall be done after shock test.

- The flight unit shall be subjected to acceptance vibration in Sine, Random and Shock in all three axes to levels as in Table 1, Table 2 & Table 3. During acceptance test nominal cord pre-load shall be applied. The health of all the relays in the circuit and the devices for providing feedback to vehicle shall be monitored and recorded. After the completion of the vibration tests (sine & random) a functional separation test shall be conducted. Similarly functional separation test shall be done after shock test.

3.7.1.2 For Systems with flight heritage

- A separation system that has prior flight heritage shall be subjected to acceptance testing alone as in Table 1, Table 2 & Table 3. The qualification test levels of a system that has flown in a vehicle other than PSLV, shall have compliance with levels as in Table 1, Table 2 & Table 3. Any non-compliance shall be mutually discussed and re-tested if required.

Table 1 Sine vibration test level - Specification

	Frequency Range-Hz	Qualification Test level	Acceptance Test level
Longitudinal	5.0-10	10 mm (0-peak)	8 mm (0-peak)
Axis	10.0-100.0	4.5 g	3 g
Lateral	5.0-8.0	10 mm (0-peak)	8 mm (0-peak)
Axis	8.0-100.0	4.5 g	3 g
Sweep rate		**2 Oct/min**	**4 Oct/min**

Table 2 Random vibration test level - Specification

Frequency (Hz)	Qualification PSD (g^2 / Hz)	Acceptance PSD (g^2 / Hz)
20	0.002	0.001
110	0.002	0.001
250	0.034	0.015
1,000	0.034	0.015
2,000	0.009	0.004
g RMS	**6.7**	**4.47**
Duration	**2 min/axis**	**1 min/axis**

Table 3 Shock test levels

Qualification test level	105g, 2ms
Acceptance test level	70g, 2ms

After completion of each of the above tests (in each axis) the tension of the cord, status of switches, status of S/C RF systems, status of relays shall be verified and data recorded before start of the subsequent test.

3.7.2 Thermo-vaccuum test

The separation system shall be subjected to thermo-vaccuum test. The cycling of the system shall be done at 263K to 323K at 10^{-5} Torr pressure. A functional separation test shall be conducted in vaccuum condition.

3.7.3 Material Specification

The materials used shall conform to outgassing requirements of TML, CVCM and WVR specifications as follows.

TML	<1%
CVCM	< 0.1%

3.7.4 Compatibility checks with PSLV EB

The following compatibility checks will be conducted with flight EB, 2 months before launch at ISRO premises.

a. Mechanical interface verification

b. Electrical compatibility check with flight Equipment Bay to verify the isolation and continuity between vehicle and separation system electronics.

c. Verification of grounding between separation system and vehicle.

d. Three functional tests (employing flight Prime battery alone, redundant battery alone, both flight and redundant batteries) to confirm the electrical compatibility and monitoring loops.

3.8 Documentation

The following documents to be provided to PSLV before accepting for launch services.

a. Separation System configuration, design and flight heritage

b. Satellite configuration including RF system

c. Satellite Design Report concerning details relevant to PSLV interfaces : Launch – 1 year

d. Overall elements and safety features

The following reports shall be made available to ISRO Review team. The Review team will have the final authority to clear the use of the User supplied separation system.

a. Separation system Design Report : Launch – 1 year

b. Qualification and Acceptance Test Reports – Vibration, Shock, functional, thermo-vac tests & any other specific test recommended by the review committee. : Launch – 4 months (for new systems) and Launch – 1 year for heritage systems

c. FMECA report of the system : Launch – 4 months (for new systems) and Launch – 1 year for heritage systems

The time-line mentioned will be the minimum duration. Actual launch will be finalized based on the manifest of PSLV. All the above reports shall be presented by the customer team to the ISRO review committee latest by four months before launch.

3.9 Satellite design

a. The satellite shall be designed for loads as defined in Section 3.1

b. The satellite longitudinal and lateral structural frequencies shall be 1.5 times that of separation system frequency.

c. The satellite shall ensure proper grounding to the vehicle through the separation system. The mounting interface shall be conductive & the contact resistance between the satellite and separation system shall be less than 100 mΩ.

d. The satellite and separation system battery shall be charged finally at Launch -12days (min) before integration to PSLV.

e. The separation system along with the satellites shall be available for integration with vehicle one month before launch.

f. Thermal baking shall be done for 24hrs at 323K and 10^{-5} Torr pressure

g. Li-Ion batteries shall be qualified to withstand PSLV flight loads

3.9.1 Satellite RF systems

a. The frequency of the RF systems viz. beacon and transmitter shall be kept away from vehicle frequencies. It is preferable to avoid 430-438 MHz for satellite transmitter and beacon. Clearance shall be obtained from PSLV for any non-compliance.

b. The satellite including the RF systems shall be in power OFF state from the time of assembly for a duration as specified in Table 4

c. It is essential to provide the details of electrical circuit of the RF system used in S/C to PSLV for review.

Table 4 Power ON sequence for Nano-satellites

Satellite power ON		Earliest at the instant of separation
RF systems	RF beacon and Transmitter ON	Satellite power ON + 30 minutes
	RF Receiver ON	With satellite power ON

3.10 Ordnance and Propulsion Systems

A detailed description of the ordnance and propulsion subsystems of the spacecraft containing the following details shall be provided.

- Function of the system
- Location of the system
- Operation of the system
- System design parameters (Pressure vessels shall have a min margin of 1.5 on proof pressure)
- System test parameters
- System operating parameters
- Packing and handling procedures
- Effects due to inadvertent operation of the ordnance system
- General precautions and precautionary provisions made
- The applicable hazard classifications, including class, division, and compatibility group
- The ordnance device and system hazard category for each ordnance item and system; test results and/or analysis used to classify the ordnance devices and systems as Category A or B

- Part number, manufacturer, and net explosive/propellant weight for each ordnance item/propellant

3.11 Compliance Matrix

Any non-compliance to the following matrix shall be mutually discussed before implementation.

S. No	Requirement		Compliance status	Remarks
1.	Design Loads	± 11g longitudinal		
		± 6g lateral		
2.	Frequency	>90 Hz longitudinal		
		> 45 Hz lateral		
3.	Mechanical Interface	4 Nos / 6 Nos M5 fasteners		
4.	Mounting for radial separation			
5.	Surface protection			
6.	Separation velocity	1 to 2 m/s		
7.	Breaking strength of cord	5 times pre-load		
8.	Monitoring the cord pre-load			
9.	Selection of cord for flight use			
10.	Conditioning of cord for flight use	Loaded to 1.25 times of pre-load for one hour before flight assembly		
11.	Relaxation of the cord pre-load in assembled condition for a period of minimum of 1 month	<20%		
12.	Functional test after evaluation of pre-load			

S. No	Requirement		Compliance status	Remarks
	relaxation			
13.	Isolation of Separation system Electrical circuit from vehicle			
14.	Electrical power to the separation system	Within the separation system		
15.	PSLV command	28V, 500ms, 500 mA (max)		
16.	Circuit configuration	2S-2P for relays and battery		
17.	Spike suppression diodes	Across Relay SET & RESET		
18.	Monitoring devices & their redundancy	Door status		
		Stroke completion status		
19.	Monitoring devices status	Normally Closed during launch		
20.	Non-intrusive current monitoring of the relay coil current	Using Hall Effect sensor		
21.	Interface connector type and redundancy	MIL grade 9pin, 15pin or 25pin D-type		
22.	Qualification unit/qualified levels	Sine vib.		
		Random vib.		
		Functional sepn. test		
		Shock test		
		Functional sepn. test		
		Relay monitoring during test		
		Feedback device monitoring during test		
23.	Flight unit	Sine vib.		

S. No	Requirement		Compliance status	Remarks
		Random vib.		
		Functional sepn. test		
		Shock test		
		Functional sepn. test		
		Relay monitoring during test		
		Feedback device monitoring during test		
24.	Thermo-vaccuum	263K 10^{-5}Torr		
		323K 10^{-5}Torr		
		Functional sepn. test		
25.	Material specification	TML		
		CVCM		
		WVR		
26.	Compatibility with EB	Mechanical interface		
		Electrical contnuity		
		Electrical isolation		
		Grounding		
		Flight P battery sepn test		
		Flight R battery sepn test		
		Both P & R battery sepn test		
27.	Documentation	Specification		
		Design Report		
		Vibration test plan		
		Vibration test report		

S. No	Requirement		Compliance status	Remarks
		Shock test plan		
		Shock test report		
		FMECA report		
28.	Satellite design	± 11g longitudinal		
		± 6g lateral		
29.	Satellite frequency	>135Hz Longitudinal		
		>70Hz lateral		
30.	Satellite & separation system final battery charging slot	Launch – 12 days		
31.	RF frequency of satellite	away from vehicle frequency.		
32.	Ordnance system in S/C			
33.	Propulsion system in S/C	Margin on proof pressure		
34.	Thermal baking for 24hrs	10^{-5} Torr at 323K		